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Supplementary appendix

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Appendix

Mass gatherings medicine: public health issues arising from mass gathering religious and sporting events

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Infectious diseases at the Hajj

Increased carriage of enteric pathogens have been noted, including *Tropheryma whipplei*,[1] multidrug-resistant nontyphoidal *Salmonella*,[2] extended-spectrum β-lactamase producing *E coli* and *K pneumoniae*,[3] colistin-resistant *E coli* and *K pneumoniae*, and carbapenemase-producing *E coli*.[2] Moreover, acquisition of *ctx-M* genes at the Hajj was associated with the occurrence of diarrhoea and was related to the use of β-lactams.[4] A prospective cohort study of French Hajj pilgrims[5] was done to determine the acquisition of enteric pathogens during the 2016 Hajj. Rectal swabs were done before pilgrims left France and before they returned from Saudi Arabia. Of the 117 pilgrims studied, 15 (14%) had diarrhoea during Hajj. Of the pre-Hajj samples, 37 (32%) were positive for at least one pathogen compared with 50% of post-Hajj samples. 30% of pilgrims had diarrhoea associated with enteropathogenic *E coli*, 10% with enteroaggregative *E coli*, and 7 (6%) with Shiga-like toxin-producing *E coli*. A lower prevalence of enteropathogenic *E coli* (23%) was seen in pilgrims who washed their hands more frequently at the Hajj than usually compared with others (40% [OR = 0.34; 95% CI 0·15–0·78; P = 0·017]).[5]

Non-communicable diseases at the Hajj

The 2015, 2016, and 2017 Hajj pilgrimages occurred during the summer season, when the temperatures in Mecca and Medina exceeded 45°C. Heat-related disorders at mass gatherings held in tropical countries are important health issues.[6–9] High temperatures can cause heat- related illness disorders ranging from minor ailments (eg, sunburn, cramps, leg oedema, prickly heat, and syncope) to more serious conditions (eg, dehydration, electrolyte

imbalance, shock, heat exhaustion, heat hyperpyrexia, organ failure, convulsions, increasing intracranial pressure coma, heatstroke, and mental disorders).[6–10] Many factors play have a role in the outcome of heat-related illness disorders in pilgrims, including old age, chronic disease, overcrowding, physical exertion, lack of acclimatisation, and dehydration. Elderly people are more likely to succumb to heat-related disorders owing to decreased blood flow to the skin, poor sweat gland function, and chronic cardiac, lung, and renal comorbidities.[8,11] A cross-sectional study done during the 2016 Hajj[6] looked at heat-related disorders in 267 pilgrims admitted with heat stroke, heat exhaustion, hyperthermia, and electrolyte imbalance. The mean age of the patients was 54 years (± 16 years). Common signs and symptoms among patients with heat stroke were altered mental status (50 patients, 62·5%), tachycardia (37 patients, 46·3%), and tachypnea (29 patients, 36·3%). In patients with heat exhaustion, most common signs were dizziness (40 patients, 21·4%) and vomiting (20 patients, 10·7%). Diabetes comorbidity was found in 12 of 80 (15·0%) of patients with heatstroke and 11 of 187 (5·9%) of patients with heat exhaustion. The median length of the hospital stay was 2 h (IQR 1–12h)**.–**In patients with heatstroke, 59 of 80 (84%) of patients were treated successfully and discharged and 5 patients (7%) died in critical care units.

Music concerts

The October 2017, Route 91 Harvest Country Music Festival, held in Las Vegas, was attended by more than 22 000 people. On the final day of the festival, October 2, 2017, a lone 64-year-old gunman with no political, racial, or religious agenda or history of mental illness or criminal behaviour shot dead 58 people and injured another 515 by firing thousands of rounds of ammunition from the 32nd floor of a nearby hotel.[12]

On May 22, 2017, a terrorist detonated an improvised shrapnel-laden bomb when attendees were leaving Manchester Arena at the end of a music concert, in which the American singer Ariana Grande performed. 23 people were killed and 159 people were wounded, more than half of them children.[13]

Psychological disorders following mass casualty events

After the Manchester arena attack, a survey of 1,399 people showed that the terror attack generated a range of psychological problems in the UK population,[14] such as disrupted worldviews, xenophobia, and severe stress symptoms.

Following the two terrorist attacks in France, the January 2015 Charlie Hebdo attack and the November 2015 Bataclan concert hall attack, a survey[15] found increased levels of psychological distress, posttraumatic stress symptoms, symbolic racism and unwillingness to interact with Muslims by non-Muslims. The prevalence of serious mental illness was higher after November 2015 attacks (7·0% after the first attack, 10·2% the second, $\chi 2$ (1) = 5·67, $p < 0·02$), as were posttraumatic stress symptoms (11·9% vs. 14·1%, $\chi 2$ (1) = 4·15, $p < 0·04$). Another survey found post-traumatic stress and insomnia which was associated with traditional and social media use.[16]

Preventing stampedes

Preventing stampedes at Kumbh Mela

With an ever-increasing number of pilgrims attending the Kumbh Mela, the Indian government has well prepared plans for future pilgrimages.[17–19] For the current ongoing 2019 Kumbh Mela, the Indian government has created multiple access points for pilgrims through different routes to the river and built additional temporary bridges for smoother and streamlined flow of pilgrims. Use of modern technologies, such as satellite imaging and CCTV cameras, to monitor and direct the flow of pilgrims are being taken forward used to improve the safety and health of people at the event.[17] Mobile and drone technology to optimise disease surveillance and health-care delivery is being evaluated and developed.[17] Dialogue with various community leaders of ‘akharas’ (sects) pre-determines the order of ritual baths.[20,21]

Preventing stampedes at the Hajj

With millions of pilgrims performing their religious rites close together within restricted a small space and within a specific short time period, crowd movement and flow will always be hindered, and disasters are inevitable. Previous Hajj pilgrim stampedes include: 1426 deaths

on July 2, 1990 following pedestrian tunnel fire; 270 deaths at the stoning of the Devil ceremony on 5 March, 2001; 118 deaths at Jamarat bridge on April 9, 1998; 251 deaths at the stoning of the Devil ceremony on Feb 1 2004; 346 deaths at the Jamarat Bridge on Jan 12, 2006; and 769 deaths on Sep 24, 2015 in Mina at the intersection leading to the Jamaraat bridge.[22]

Since 2015 the Saudi Arabian authorities have taken steps to improving the infrastructure and procession routes for pilgrims, including a redesigned of Jamaraat Bridge, which was completed in 2013.[18] New levels have been built at the Jamaraat, and pilgrims are able to go to the second and third floors to perform the stoning rituals, and this has eased congestion. Following the 2015 Hajj stampede and crane crash incidents, the Saudi Arabian authorities have made a $100 billion investment to in expansion of the Hajj rites' infrastructure to accommodate the needs of the ever-increasing numbers of pilgrims. According to the country's new vision 2030,[19] the number of Umrah and Hajj pilgrims will increase to 15 and 2·2 million by 2020 and 30 and 4·5 million by 2030 (Kingdom of Saudi Arabia Vision 2030.[19] This expansion includes: increasing the capacity of the 2 two main airports receiving pilgrims in Jeddah. Madinah and Medina, increasing the holding capacity of the Grand Mosque in Makkah from 600 000 pilgrims to 2·5 million by 2020, building of a high-speed railway link from between Mina to and Medina, and a fast train link between Hajj terminal in Jeddah and Makkah. Also being taken forward is innovative technology, and crowd simulation models are also being developed, to evaluate optimal methods for grouping and scheduling pilgrims and crowd management.[18] Use of modern technologies are to be used in a similar fashion to the Kumbh Mela, such as satellite imaging and CCTV cameras, to monitor and direct flow of pilgrims and to improve the safety and health of people at the event. To deal with the growing numbers of pilgrims, water-resistant electronic bracelets which are water resistant will be provided to each pilgrim. The e-bracelets have a barcode on which the pilgrim's biodata and health information is stored, including address of residence in the Kingdom of Saudi Arabia. The e-bracelet also has a prayer times alert and a compass pointing the pilgrims to where they should face when they pray.[18] The annual Hajj provides unique opportunities for research on crowd behaviour and control.

Reducing morbidity and mortality from heat-related disorders

Reducing heat-related morbidity at the Hajj

The Saudi Arabian Ministry of Health recommends several preventive measures to minimise both the communicable and non-communicable health burden, including heat-related disorders, among pilgrims during the Hajj.[8] One recommendation is that pilgrims use umbrellas when walking in areas exposed to direct sunlight. Umbrellas will be distributed to each pilgrim on arrival at the Jeddah International Airport Hajj Terminal and at Hajj premises at no cost to the pilgrims by both the Ministry of Health and other non-governmental organisations. Umbrellas that are equipped with fans are also being developed.

Pilgrims receive health education and pictorial messaging advising them on the importance of protection from heat and sun exposure and keeping well hydrated.[23] Ongoing investments include the addition of air-conditioning units to tents and the installation of fans that spray water across the pathways between tents and camp sites. The marble surroundings at the Grand Mosque in Mecca are equipped with a cooling system that works on all levels. Huge folding umbrellas are installed in the courtyards of the second Grand Mosque in Medina. Other measures being taken are distancing of pedestrians from vehicles, provision of shaded roads and rest areas, provision of ample amounts of quality drinking water in all Hajj locations, and easy access to health services.

Tokyo 2020 Summer Olympics

Preparations for Tokyo 2020 Summer Olympics in Japan are underway. During the heat wave in Japan in July, 2018, temperatures reached 41°C and around 22 000 people, half of them elderly, were taken to hospital with symptoms of heat stroke.[24,25] Prevention of heat-related disorders in the anticipated hot climate of the Tokyo 2020 Summer Olympics[26] will be a priority issue for organisers, in addition to the focus on infectious diseases.[27,28]

The 2015 MERS-CoV outbreak

The 2015 MERS-CoV outbreak in South Korea, in which 184 MERS cases, including 33 deaths, occurred in 2 months, was imported from the Middle East by a South Korean businessman who had travelled to Saudi Arabia.[29] Since then, public health institutions and academics

have called on the international community and Middle Eastern countries to make resources available for establishment of a 'One Human-Environmental-Animal Health' global network for proactive surveillance, rapid detection, and prevention of MERS-CoV and other epidemic infectious diseases.[30,31] This should be aligned closely to the Sendai framework for disaster risk reduction.[32] Although several small cohort studies have been published on the prevention, transmission, and occurrence of and bacterial respiratory tract infections in Hajj pilgrims,[33] further large cohort studies of pilgrims from various geographical regions are needed to provide a comprehensive evidence base regarding the risk factors, transmission dynamics, pathogenesis, effects on health services, management outcomes, and globalisation upon their return to their home countries.[32,33] The acquisition of MERS-CoV has not yet been a major issue at the Hajj, and surveillance and screening of pilgrims who fall ill after returning from Hajj is required owing to its continued circulation in Saudi Arabia.[4,29]

Defining the public health risks and threats, and their consequences, at mass gatherings will require multinational studies of pilgrim cohorts using similar methods so that accurate data regarding surveillance, transmission, and effects can be ascertained, compared, and used for mitigation of the risk of global spread. The Saudi Arabian Government continuously reviews global threats and strengthens surveillance systems operating at the Hajj.[34] Meanwhile promotion of appropriate personal protection measures, such as face masks, personal hygiene measures,[23,30,35–37] and travel-related vaccines should remain a priority.

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